The IceCube Computing Model

Steve Barnet
University of Wisconsin – Madison
IceCube Collaboration
Overview

- The Basics of IceCube
- Data Handling
- Computing Model
- Summary
What is IceCube?

- 250 people
- 39 Institutions
- 11 Countries
- Exotic Locales
The IceCube Neutrino Observatory

- A kilometer scale neutrino detector
- Located at geographic South Pole
- Detects Cherenkov light from neutrino interactions
- Sensitive to energies down to about 10 GeV
Location, Location, Location

- Why the South Pole?
- Lots of ice – a great detection medium
- The ice is very clear
- Thick ice sheet – sensors deep enough to provide significant background reduction
The Detector(s)

• Actually three detectors
  – IceCube baseline detector – 100 GeV
  – IceTop air shower array – 300 TeV
  – DeepCore extension – 10 GeV
IceCube Baseline Configuration

- Digital Optical Modules (DOMs) - Photomultiplier Tubes and supporting electronics
- Deployed on 80 vertical strings, each with 60 DOMs
- Spaced out on a 125 meter grid covering 1 km$^2$ on the surface
- Vertically, 17 meters apart at depths between 1450 and 2450 meters
DeepCore extension

- Six additional strings beyond baseline
- PMTs have higher quantum efficiency
- Tighter spacing
- Extends energy sensitivity down to about 10 GeV
IceTop Air Shower Array

• 160 tanks filled with ice
• 2 DOMs per tank
• 2 tanks spaced 10 meters apart at the top of 80 baseline strings
• Used for study of cosmic ray air showers
• Sensitive to 300 TeV
IceCube Lab

IceTop
- 81 Stations, each with
  - 2 IceTop Cherenkov detector tanks
  - 2 optical sensors per tank
  - 324 optical sensors

IceCube Array
- 86 strings including 8 DeepCore strings
- 60 optical sensors on each string
- 5160 optical sensors

December, 2010: Project completed, 86 strings

DeepCore
- 8 strings-spacing optimized for lower energies
- 480 optical sensors

Eiffel Tower
- 324 m

Bedrock
Drilling and Deployment

- Hot water drill with ~5 MW output
- Drilling takes 26-30 hours per hole
- Strings deployed in ~ 20 hours
  - DOMs get final test
  - Attached to surface cable
  - Lowered into hole
- About 1 month to completely re-freeze
Construction is complete

• First string deployed in 2004-2005 season
• Detector completed in 2010-2011 season.
Online Processing

DOM Hubs → Event Builder → Triggering and Filtering → Data Transfer → North via Satellite

Raw → Filtered

Raw → Tape
Data Volume

- Event rate of 3000 Hz
- 1 TB/day raw data
- Reduced to 105 GB/day
  - Based on available satellite bandwidth
- Tapes shipped North every year
The North
Data Production

• Level 1
  - Filtered stream from Pole

• Level 2
  - Basic path reconstruction of upgoing muons
  - Good reconstructions of downgoing muons
  - Deal with coincident muons

• Level 3 – set by each working group
  - Event selection
  - Stream separation
Simulation

- **Event generation**
  - CORSIKA for cosmic ray background
  - Several neutrino generators

- **Photon propagation**
  - Lookup tables
  - Direct simulation on GPUs

- **Detector simulation**
Simulation Framework

• Software framework to coordinate components
• Central DB at UW-Madison to coordinate and track production
• First versions were monolithic – photonics tables made grids difficult
• Newer versions broken into finer steps
Computing Model

• University of Wisconsin - Madison – Tier 0
  – Raw data collection and archive
  – Data production to Level 3
  – Coordinate simulation production

• DESY-Zeuthen – Tier 1
  – Second copy of Level 2 data
  – Hold simulation data sets in Europe
UW Overview
Tier 0 Capacity

- **Compute cluster**
  - 1200 cores, at least 2 GB/core memory
  - Approximately 16,000 HEPSpec06

- **Experimental data**
  - 1 PB Lustre filesystem

- **Simulation data**
  - 1.2 PB Lustre filesystem

- **Analysis data sets**
  - 250 TB Lustre filesystem
Tier 1 Capacity

• Grid CPU
  – 384 cores
  – Approximately 6300 HEPSpec06

• Storage
  – 360 TB dCache
  – 150 TB Lustre

• Local CPU
  – 1000 cores
  – Approximately 13,800 HEPSpec06
Simulation Production

- Driver of our distributed computing
- Collaboration institutions contribute to simulation production
- Production is coordinated with a central DB at UW Madison
- Output is collected at either DESY-Zeuthen or UW Madison
Feeding the Grids

- **US institutions**
  - Tend to be local institution resources
  - Otherwise OSG resources

- **European institutions**
  - LHC grid resources
  - Regional grid resources

- **GridFTP** — lowest common denominator
Organizational Keys

- Tier 0 – own and operate resources
- Good partner – DESY-Zeuthen Tier 1
- Good collaborators
- Great UW campus network group
  - Flexible
  - Committed to supporting research
Future

• Rainbows and unicorns from here?
• Storage
  – Storage management – scaling
  – Data management – scaling
  – Data movement
• Computing
  – Stronger GPU emphasis
  – Better grid integration
  – Clouds?
Summary

• IceCube is a km scale neutrino detector
• Can make good use of dramatically scaled down LHC techniques
• Good partners and good collaborators smooth the path
• We may not be the coolest experiment on the planet, but we are one of the coldest.
Questions?